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Code comparison of coupled thermo-hydro-mechanical processes induced by cold CO_2 injection in deep saline aquifers

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We summarize the results obtained from a code-inter-comparison study developed within the TRUST project financed by the European Community's 7th Framework Programme. The study addresses simulation of coupled thermo-hydro-mechanical processes induced by the injection of carbon dioxide (CO_2) in deep saline geological formations. Four numerical simulators are used to model non-isothermal multi-phase flow in deformable porous media, and the effects of interests arising during CO_2 injection (e.g., CO_2 plume shape, fluid pressure and temperature evolution, deformation, etc.) are compared. Such code-inter-comparison/benchmarking, which represent a methodology for verifying, testing and comparing available modelling tools, have increased in popularity during the last decades.

Three benchmark test examples are defined with gradual increase in their physical complexity, starting with a two-phase two-component isothermal problem, then including non-isothermal effects, and finally, geomechanics. The reservoir properties are defined from mean calculated parameters from a database of approximately 2500 reservoirs.

The first benchmark example proposes CO_2 injection through a vertical well in a homogeneous, isotropic, horizontal deep saline aquifer without considering mechanical, chemical and thermal effects. The second benchmark test extends the scope of the first test by incorporating non-isothermal effects resulting from cold CO_2 injection. The third example addresses the geomechanical effects induced by CO_2 injection in order to assess caprock integrity. An industrial scale injection rate of 30 kg/s, which corresponds to approximately 1 Mt/year, is simulated. Due to the symmetry of the problem, the domain is solved either using an axisymmetric two-dimensional model, a quarter of the domain, or a slice ("piece of cake") of the reservoir, depending on the computational resources and the specifications of each software.

Simulation results show that all codes can solve the highly coupled non-linear system of partial differential equations and that they are in fairly good agreement with each other. Yet, differences arise for some results. The sources of discrepancies come from differences in the equations of state of brine and CO_2, in the discretization methods, or implementation. By conducting a series of result inter-comparison sessions, the groups were able to improve the quality of results and identify errors.